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NWC TP 5705
Volume 2

✓ 157

Low Cost/Optimized Performance Inlets, Volume 2, Phase Two, Production Methods Development

by
J. L. Arnquist
E. L. Koetje
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Boeing Aerospace Company
for the
Propulsion Development Department

JUNE 1976



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R. G. Freeman, III, RAdm., USN Commander

G. L. Hollingsworth Technical Director

FOREWORD

This report, Volume 2, describes an effort to develop fabrication methods for low cost production of inlets for an advanced long range air-to-air missile. Volume 1 of this series presents the cost/performance trade studies and the detailed design for a two-dimensional external compression inlet. The investigation was conducted during the period December 1974 through November 1975. The work was sponsored by the Naval Weapons Center (NWC), China Lake, California, under Navy Contract N00123-73-C-2225 and supported by the Naval Air Systems Command under AirTask A3303300/008B/3F31334300.

Mr. R. Reid was the Navy Technical Coordinator and has reviewed this report for technical accuracy.

This report is released for information at the working level and does not necessarily reflect the views of NWC.

Released by
G. W. LEONARD, Head
Propulsion Development Department
20 April 1976

Under authority of
G. L. HOLLINGSWORTH
Technical Director

NWC Technical Publication 5705, Volume 2

Published by Technical Information Department
Collation Cover, 24 leaves
First printing 210 unnumbered copies

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 18 NWC TP-5705-VOLUME 2 ✓	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 LOW COST/OPTIMIZED PERFORMANCE INLETS, VOLUME 2, PHASE TWO, PRODUCTION METHODS DEVELOPMENT.	5. TYPE OF REPORT & PERIOD COVERED Final rept. Dec 74- Nov 75	
7. AUTHOR(s) 10 J.L./Arnquist, E.L./Koetje R.F./Northrop	8. CONTRACT OR GRANT NUMBER(s) 15 N00123-73-C-2225 ✓	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Boeing Aerospace Company P.O. Box 3999 Seattle, Washington 98124	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 Air Task A3303300/008B/ 3F31334300	
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Weapons Center China Lake, California 93555	12. REPORT DATE 11 June 1976	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 54p.	13. NUMBER OF PAGES 42	
16. DISTRIBUTION STATEMENT (of this Report) Distribution limited to U.S. Government agencies only; test and evaluation; 19 April 1976. Other requests for this document must be referred to the Naval Weapons Center.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Low cost inlet Missile performance Ramjet inlet Missile cost Trade studies Fabrication methods Cost vs. performance Titanium forming		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) See back of form.		

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(U) *Low Cost/Optimized Performance Inlets. Volume 2, Phase Two, Production Methods Development*, by J. L. Arnquist, E. L. Koetje and R. F. Northrop, Boeing Aerospace Company. China Lake, Calif., Naval Weapons Center, June 1976, 42 pp. (NWC TP 5705, Volume 2, publication UNCLASSIFIED.)

(U) Volume 1 of this report covers phase one of a study to identify, design and fabricate low cost/optimized performance inlets for an advanced long range air-to-air missile. This report, Volume 2, covers the phase two effort to develop fabrication methods for low cost production of inlets. Production methods were developed for low cost forming and welding of titanium sheet metal for the inlet. The resulting hardware has internal features identical to the production hardware. Production hardware costs and weights were re-estimated based on recommended design changes. A set of "close tolerance" inlets for use in freejet testing was also produced in heavy steel plate material.

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ACKNOWLEDGMENT

The authors are indebted to the many people in the Boeing Aerospace organization who contributed to the performance of this study. Worthy of special note are the efforts of Oren Ross for expediting of the fabrication effort, Gary Jensen and Eva Cornelius for preparation of the manuscript, and J. A. Beasley and H. W. Klopfenstein for overall guidance.

NOMENCLATURE

Boeing	Boeing Aerospace Company
C	Celcius
cm	Centimeter
F	Fahrenheit
FMS	Fuel Management System
GFE	Government Furnished Equipment
in	Inch
kg	Kilogram
lb	Pound
M	Moment
MRE	Modern Ramjet Engine
mm	Millimeter
NWC	Naval Weapons Center, China Lake
P	Load
Q	Lateral Load
T	Torque
TIG	Tungsten Inert Gas
UARL	United Aircraft Research Labs (Now UTRL)
UTC	United Technology Corporation
V	Vertical Load
μ "	Microinch

INTRODUCTION

The upward trend in weapon systems costs in the recent past has led to increased emphasis being placed on low cost. It has become apparent that low cost should have as much emphasis as high performance. The basic rationale behind the "Design to Cost" philosophy is that there is a trade between cost and performance which must be considered during the early concept stages of a system development.

The study outlined in this report has been based on the premise that such a trade exists and must be considered if low cost production hardware is the goal.

Volume 1 of this report covers the development of missile performance and cost sensitivities to inlet design and fabrication parameters, trade studies, and selection of a preferred formed and welded titanium sheet metal design.

Volume 2 covers the development of fabrication methods for low cost production of inlets. One inlet was fabricated using materials and methods anticipated for production hardware, resulting in an inlet with internal features identical to the production design. In addition, a set of two inlets were built for use during freejet testing of the MRE propulsion system. These inlets were made of heavy plate steel and incorporated the close tolerances, smooth finishes and sharp corners typical of wind tunnel test inlets.

SUMMARY

Two close tolerance inlets were fabricated for use by NWC in free-jet testing of the MRE propulsion system. These inlets were made of heavy plate steel and incorporated the close tolerances, mirror finishes, razor sharp leading edges, and square corners typical of the earlier subscale models used for development of the inlet configuration. Figure 1 shows an overall view of these two inlets.

One inlet was built using materials and methods anticipated for the large scale production of flight weight inlets. Methods were developed for forming of the 5.1 mm (0.20 in.) thick titanium sheet metal to the required contours, welding of various formed sections to make up the basic inlet and finishing of leading edges and interface areas. This effort resulted in the hardware shown in Figure 2 which has internal features identical to the production design.

The results of this developmental effort were used to reevaluate the costs and weight of the production design. Several design changes were also recommended. Average production cost of the inlets was estimated to be \$3,390 per set, in mid 1974 dollars, based on a production quantity of 1000 sets. This figure compares favorably with the previous estimate of \$4,985 per set which was developed in phase I of this study for trade study purposes.

The weight of the production inlet was reestimated at 47.2 kg (104 lb.) compared to the previous estimate of 48.6 kg (107 lb.) used in the Phase I trade study.

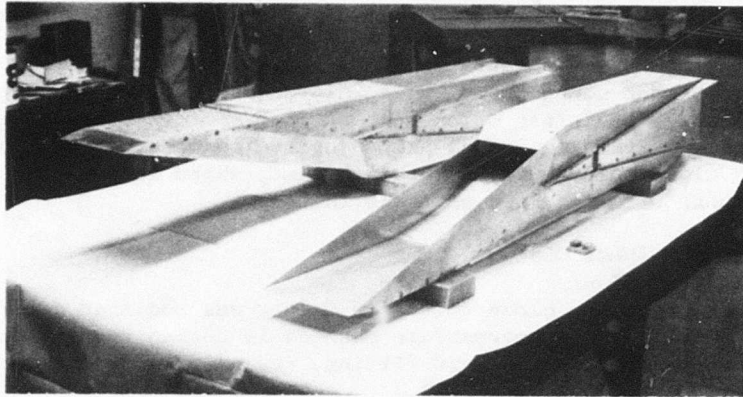


Figure 1: COMPLETED "CLOSE TOLERANCE" INLET HARDWARE.

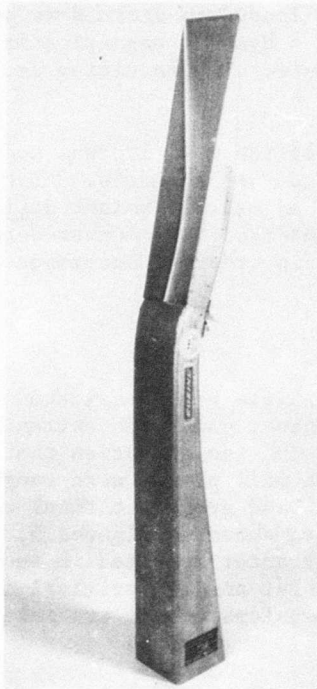


Figure 2: COMPLETED TITANIUM DUCT PORTION
OF "PRODUCTION SIMULATION" INLET.

FABRICATION OF CLOSE TOLERANCE
INLETS FOR FREEJET TEST

A set of inlets was fabricated for use by NWC/UTC in freejet testing of the MRE combustor. These inlets were built to Boeing drawing 180-54088. The inlets were built of 12.7 mm (1/2 in.) and 15.9 mm (5/8 in.) thick stainless steel plates bolted together at the corners of the duct. Close tolerances, smooth finishes, sharp leading edges and square corners were required on these inlets.

CLOSE TOLERANCE INLET DESIGN

The design of the close tolerance inlets was modified prior to fabrication in order to accommodate changes in design requirements. Changes were made to the forward fitting, cowl lip, and diverter.

The forward attachment fitting was strengthened to withstand the increased tunnel unstart loads. Figure 3 shows the envelop of possible vertical loads applied to each inlet in the event of tunnel unstart. These loads are defined as being rapidly applied and, thus, require use of a dynamic magnification factor of 2 for purposes of structural analysis. The resulting revised inlet interface loads are shown in Figure 4.

The internal detail of the cowl lip was modified to match the detail of the subscale wind tunnel models. Also, the diverter was changed to a fixed rather than an adjustable height design upon receipt of a firm decision on diverter height from NWC. Other detail changes were made as the fabrication proceeded in order to accommodate vendor fabrication capabilities.

FABRICATION METHODS

The close tolerance inlets were fabricated by Huntley Machine & Tool Co., Seattle, Washington, under subcontract to Boeing. Standard shop practices were used with the exception that the 12.7 mm (1/2 in.) thick stainless steel duct wall plates were rough formed by "chipping" on a brake press and then hand ground to final contour. Several views of the completed inlets are shown in Figures 5, 6 and 7. Excellent workmanship by the subcontractor resulted in smooth internal surface finishes throughout the inlet and all critical dimensions were within tolerances. Critical dimensions on the two inlets are summarized in Table 1.

Figure 8 shows the FMS probe and splitter installed in the inlet throat. The 15.9 mm (5/8 in.) diameter boss at the top of the splitter can be seen protruding into the airstream approximately 2.03 mm (0.08 in.). The splitter was designed and fabricated by UTC and

provided as GFE to Boeing for installation in the inlet. Detailed inspection of the splitter and review of the UTC drawing indicated this boss protrusion was within design tolerances. Boeing considered the protrusion into the airstream to be an undesirable condition. The inlets were shipped with the splitters installed and special note made of this condition.

"As Built" Drawings

"As built" drawings of the close tolerance inlets were prepared and are shown in Figure 9.

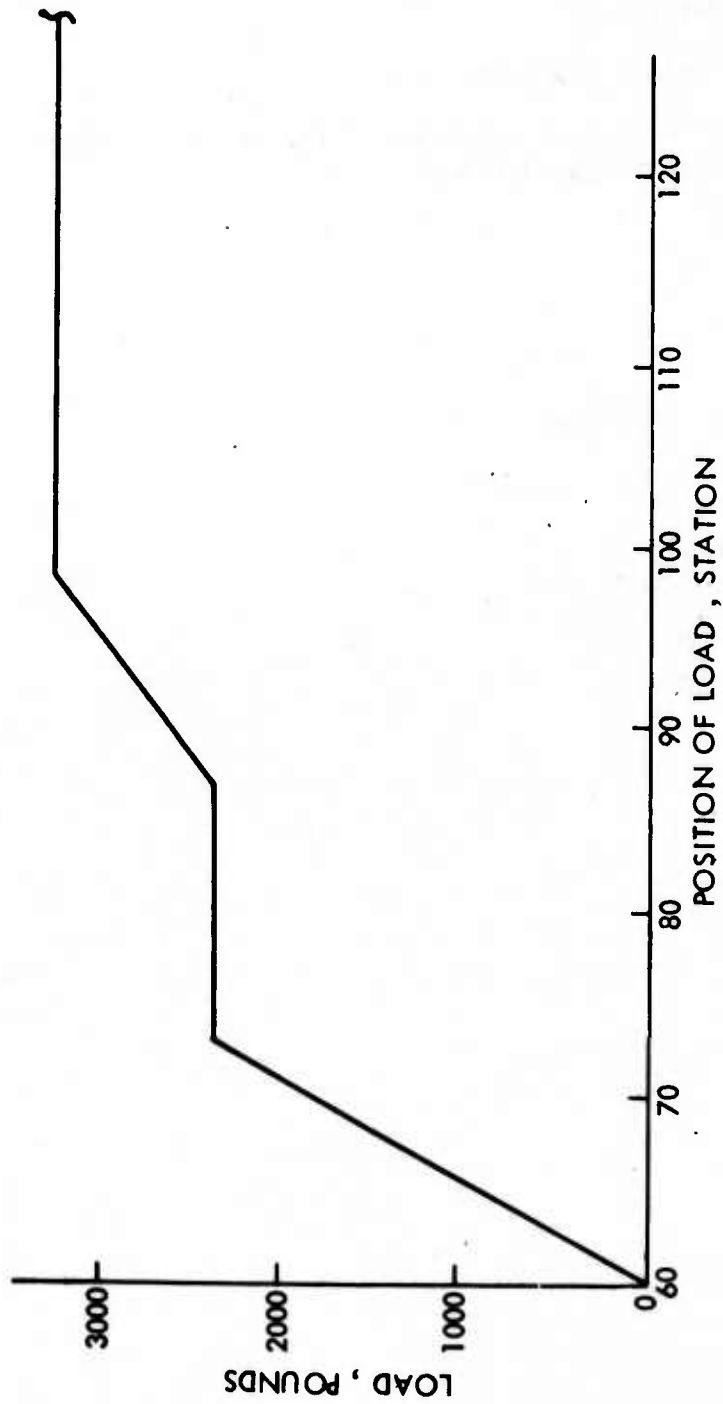


Figure 3 : MAXIMUM LOADS ON INLET FOR TUNNEL UNSTART.

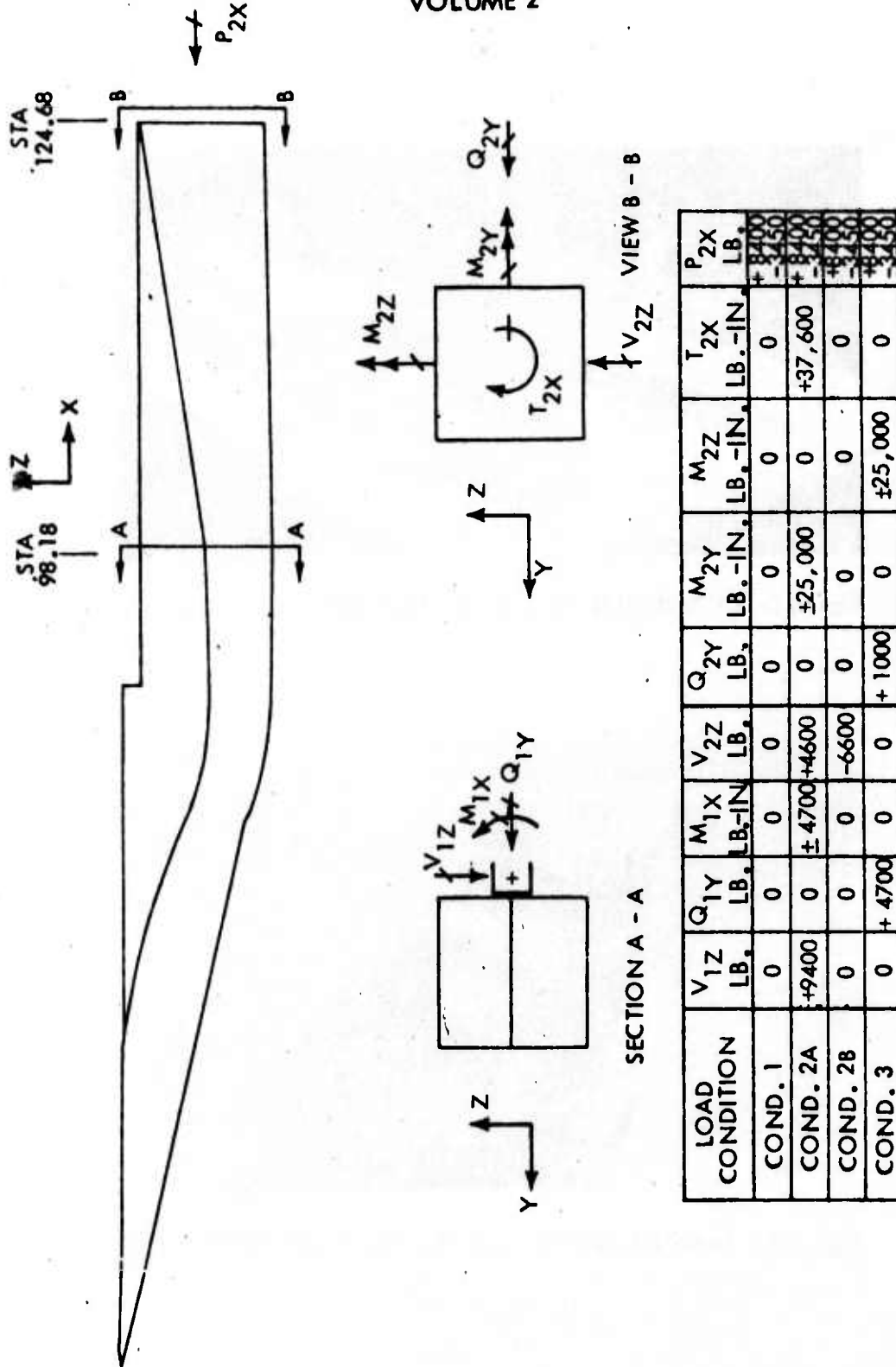


Figure 4 : REVISED INLET INTERFACE LOADS FOR FREEJET TEST DESIGN ONLY.

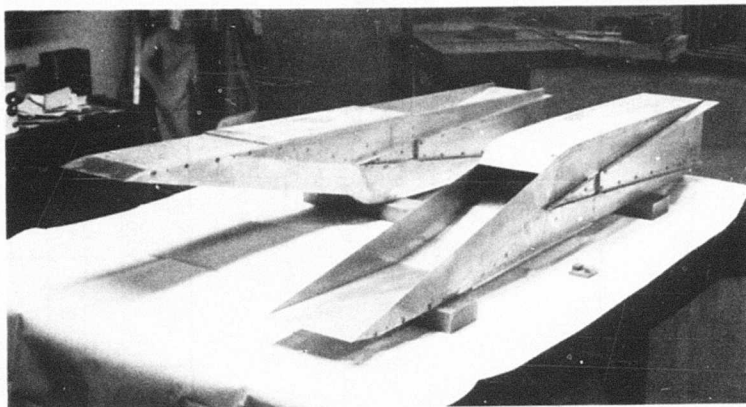


Figure 5: COMPLETED "CLOSE TOLERANCE" INLET HARDWARE.

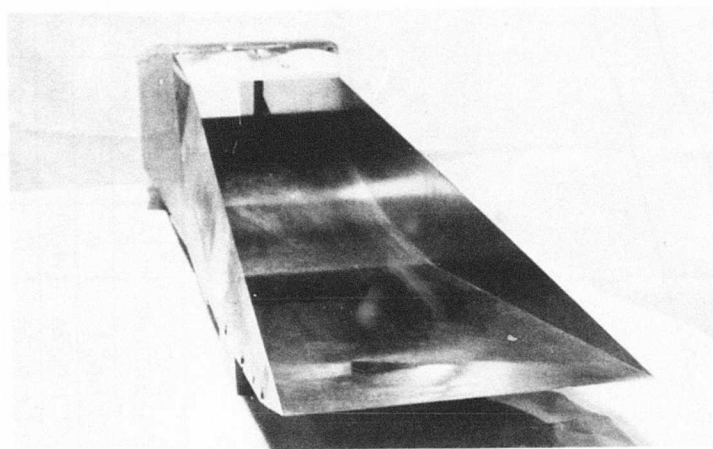


Figure 6: RAMP CONTOUR ON "CLOSE TOLERANCE" INLET.

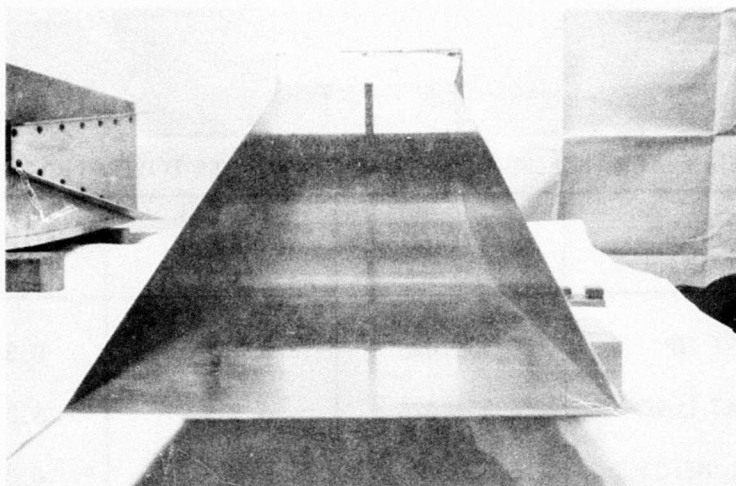


Figure 7 : FRONT END VIEW OF "CLOSE TOLERANCE" INLET.

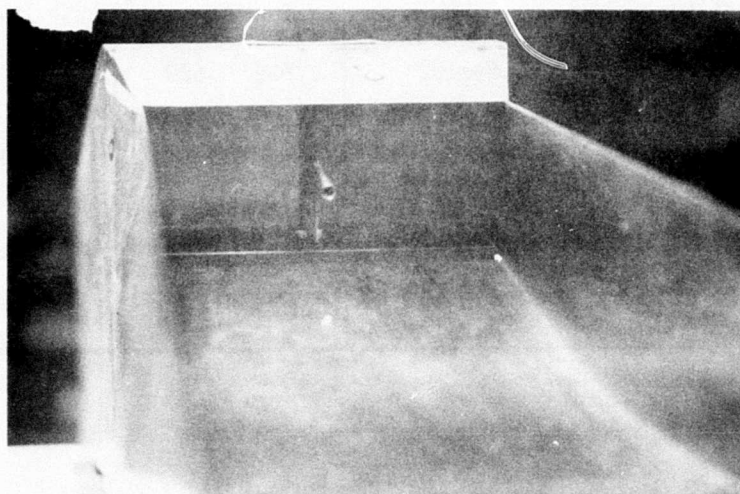


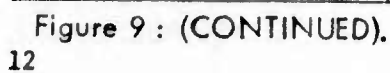
Figure 8 : FMS PROBE AND SPLITTER INSTALLATION IN
"CLOSE TOLERANCE" INLET.

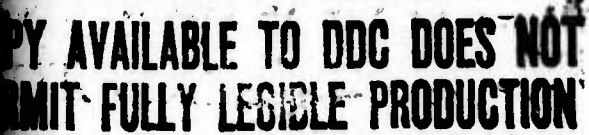
Table 1 : CRITICAL DIMENSIONS ON "CLOSE TOLERANCE" INLETS.

CRITICAL DIMENSION	DRAWING REQ'MT	ACTUAL LEFTHAND INLET	ACTUAL RIGHTHAND INLET
WIDTH AT TIP	8.33±.025	8.355	8.355
WIDTH AT THROAT	6.33±.025	6.335	6.330
CAPTURE HEIGHT	6.33±.02	6.328	6.310
RAMP ROUGHNESS	32✓	LESS THAN 32✓	LESS THAN 32✓
THROAT ROUGHNESS	64✓	LESS THAN 32✓	LESS THAN 32✓
DIFFUSER ROUGHNESS	125✓	LESS THAN 64✓	LESS THAN 64✓
BLEED VENTURI	0.64±.02	.638 - .620	.627 - .620
INTERNAL CONTOUR RAMP & COWL	±.015	±.015	±.015
PROBE STRUT ALIGNMENT TO C	±0.5 DEGREES	±0.25 DEGREES	±0.25 DEGREES
TOTAL LENGTH	64.88±.10	64.82	64.83



11





FABRICATION OF "PRODUCTION SIMULATION" INLET

One left hand "production simulation" design inlet was fabricated in the Boeing shops. The objective of this effort was to develop and demonstrate production processes for fabrication of the basic duct portion of the inlet, and to complete the inlet to the extent necessary for demonstration of internal performance in a wind tunnel test. The inlet duct internal features and materials are identical to those selected for the "production" design. Duct material was 5.1 mm (0.2 in) thick 6Al-4V titanium sheet metal with "as formed" surface finishes.

"PRODUCTION SIMULATION" INLET DESIGN

The design of the "production simulation" inlet per Boeing drawing 180-54087 was modified early in the Phase II effort in order to accommodate changes in design requirements. Specifically the requirement for freejet test was changed to wind tunnel test with attachment interfaces to be determined at a later date. The revised inlet design is shown in Figure 10. The design of the aft interface area was modified to a "blank" configuration and the diverter and forward fitting were deleted. In addition, the aft fairing was deleted and the forward fairing was changed to 4.57 mm (0.18 in) thick aluminum sheet metal.

The design of the basic duct portion was not changed except to relocate the longitudinal welds from the top and bottom duct walls to the side walls. This was done in order to make the formed parts easier to produce and simplify the welding.

Additional design changes were made during fabrication and are discussed in the following paragraphs.

DEVELOPMENT OF FABRICATION METHODS

The fabrication was broken down into the four basic steps outlined in Figure 11. Step number 1 is trimming of 5.1 mm (0.20 in) thick 6Al-4V titanium sheet metal. Three sheets were required -- one each for the upper and lower halves of the duct and one for the pre-compression shroud. Step 2 is preforming the flat sheets into channel shapes. Step 3 is forming of the longitudinal contour of the three pieces. Step 4 is trimming and welding of the three pieces into the basic subassembly. Additional steps were required to finish machine the leading edge, bleed slot, and aft end details, and to add the bleed flare plates and bleed plenum to complete the inlet assembly.

The operation of preforming the flat sheets into a channel shape was accomplished by heating the coated titanium sheets to approximately 760°C (1400°F) and forming them over cold steel dies. The dies are shown in Figure 12. The formed metal was manually removed from the dies

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TABLE I
DUCT GEOMETRY -3

CONTINUITY REFERENCE LETTER	COORDINATE	
	X	Y
1	-30.90	0
2	-16.00	0
3	-0.90	6.4
4	-5.31	8.7
5	-6.8	1.11
6	-7.10	1.90
7	-6.50	1.90
8	-5.0	1.20
9	-0.2	5.0
10	+4.70	6.82
11	+12.06	6.22
12	+54.50	6.1
13	-1.82	6.50
14	+6.75	1.50
15	+2.46	7.50
16	+54.50	6.70

DUCT INSIDE, UPPER SURFACE STRAIGHT
BETWEEN ⑤-②, ③-④ (40° REF), ⑤-④
(20° REF), ⑥-④ (2° REF), ⑥-④ (92° REF).

DUCT INSIDE, LOWER SURFACE STRAIGHT
BETWEEN ④-② AND ④-⑤ (9° REF).

- 11 BLEND CHAMFER OVER THIS LENGTH
- 12 SURFACE FINISH $\sqrt{1}$ UNLESS NOTED
- 13 FILL HOLES WITH 50% SILICA GEL CEMENT FILL OR EQUIVALENT. THIN LAYER BUT WASTE THIN
- 14 TACKLE HOLE LOCATION IS AT STATION 20.50 AND 6.50 FROM THE Y REFERENCE PLANE 11
- 15 PLUS AFTER REMOVING WITH R_{10} DIA. PIN HEAD SCREEN THREADED INTO DUCT WALL 12
- 16 DRILL 1/4"-11 DIA. HOLE AND 1/4" DIA. PIN HEAD SCREEN THREADED INTO DUCT WALL IN -3 FOR BACKLAP SCREEN 11
- 17 DRILL 1/4"-11 DIA. HOLE HORIZ. TO CENTER HOLE IN 1/4" 5. THRO. 1/4" DIA. PIN HEAD SCREEN THREADED INTO DUCT WALL IN -3 FOR BACKLAP SCREEN 11
- 18 DRILL 1/4"-11 DIA. HOLE IN -3, 1/4" DIA. PIN HEAD SCREEN THREADED INTO DUCT WALL IN -3 FOR BACKLAP SCREEN 11
- 19 INTERNAL DUCT SURFACE MUST BE SMOOTH AND FREE FROM DISCONTINUITIES (PITS, BUBBLES, SCRATCHES, ETC)
- 20 MEASURE INTERNAL DUCT SURFACE FINISH AFTER REMOVING AND REPORT DATA TO ENGINEERING
- 21 AFTER COMPLETING FITUP OF -3 TO -5, REMOVE -5 AND PLUS THREADED HOLES IN -3 WITH 1/4"
- 22 DRILL 1/4"-11 DIA. HOLE IN -3 FOR HOLE LINE FITTING. DRILL 1/4" DIA. HOLE 1/4" DIA. PIN HEAD SCREEN THREADED INTO DUCT WALL IN -3 FOR BACKLAP SCREEN 11
- 23 COMP. 5 SIDE WALLS TO 0.7 -3 SERIAL CORNER
- 24 MAXIMUM GAP 0.5
- 25 THE CORN. OF CHAMFER OVER THIS LENGTH TO MATCH CONVECTION TREAD CHAMFER
- 26 BLEND CORN. OF CHAMFER OVER THIS LENGTH
- 27 BLEND LEADING EDGE OF -5 TO SUIT CONVECTION TREAD CHAMFER
- 28 APT. EDGE OF -5 TO MATCH -3 CHAMFER BOUNDARY LINE
- 29 SHOWN AS REQUIRED

- 1 MATERIAL TYPE 304
- 2 MATERIAL 304-1/2
- 3 MATERIAL 304-1/2
- 4 MATERIAL 304-1/2
- 5 DUCT SECTION NOTE 1 THE TOLERANCE
- 6 0.00 TOL. AT ALL PT.
- 7 MAXIMUM INTERNAL
- 8 CONTOUR TANGENT
- 9 RADIUS 1/4"
- 10 RADIUS 1/4"
- 11 RADIUS 1/4"
- 12 TO RADIUS
- 13 BLEND, 1/4"
- 14 PENETRANT
- 15 STRESS 1/4"
- 16 BLEND 1/4"

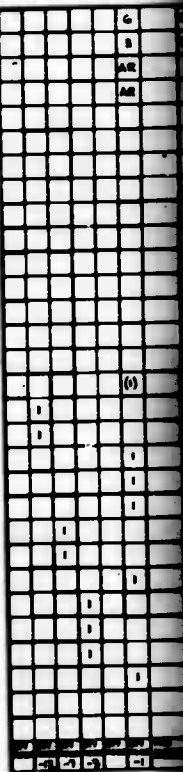
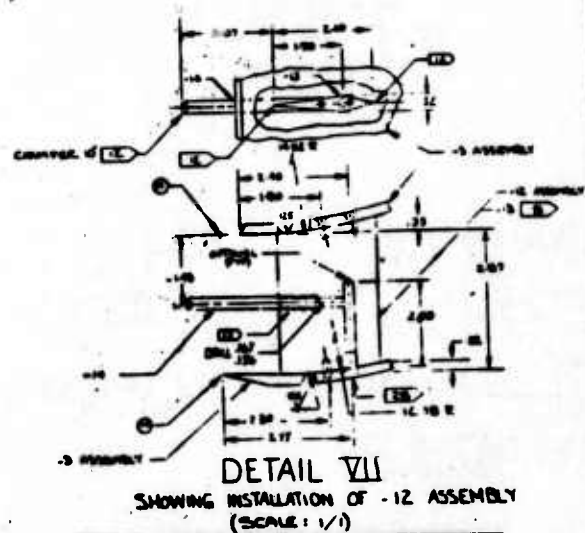
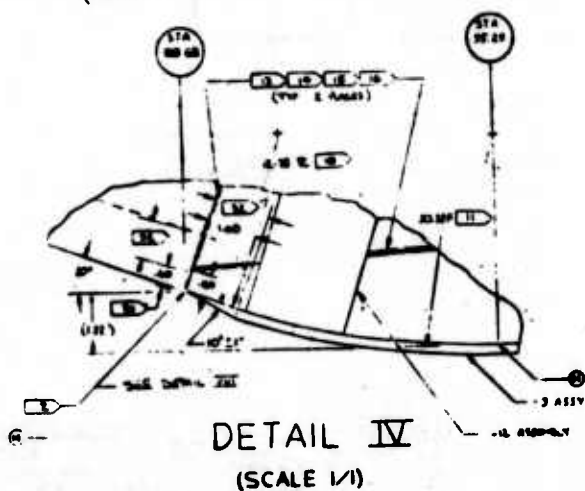
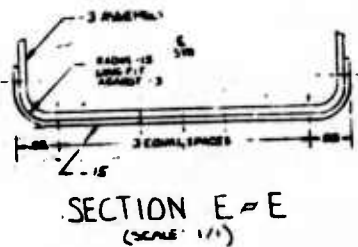
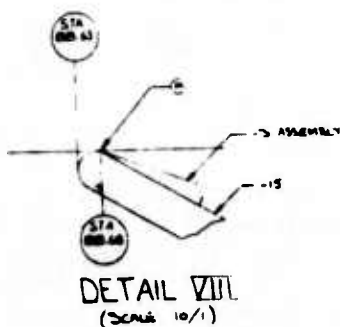


Figure 10 : INL

180-54087 ATT

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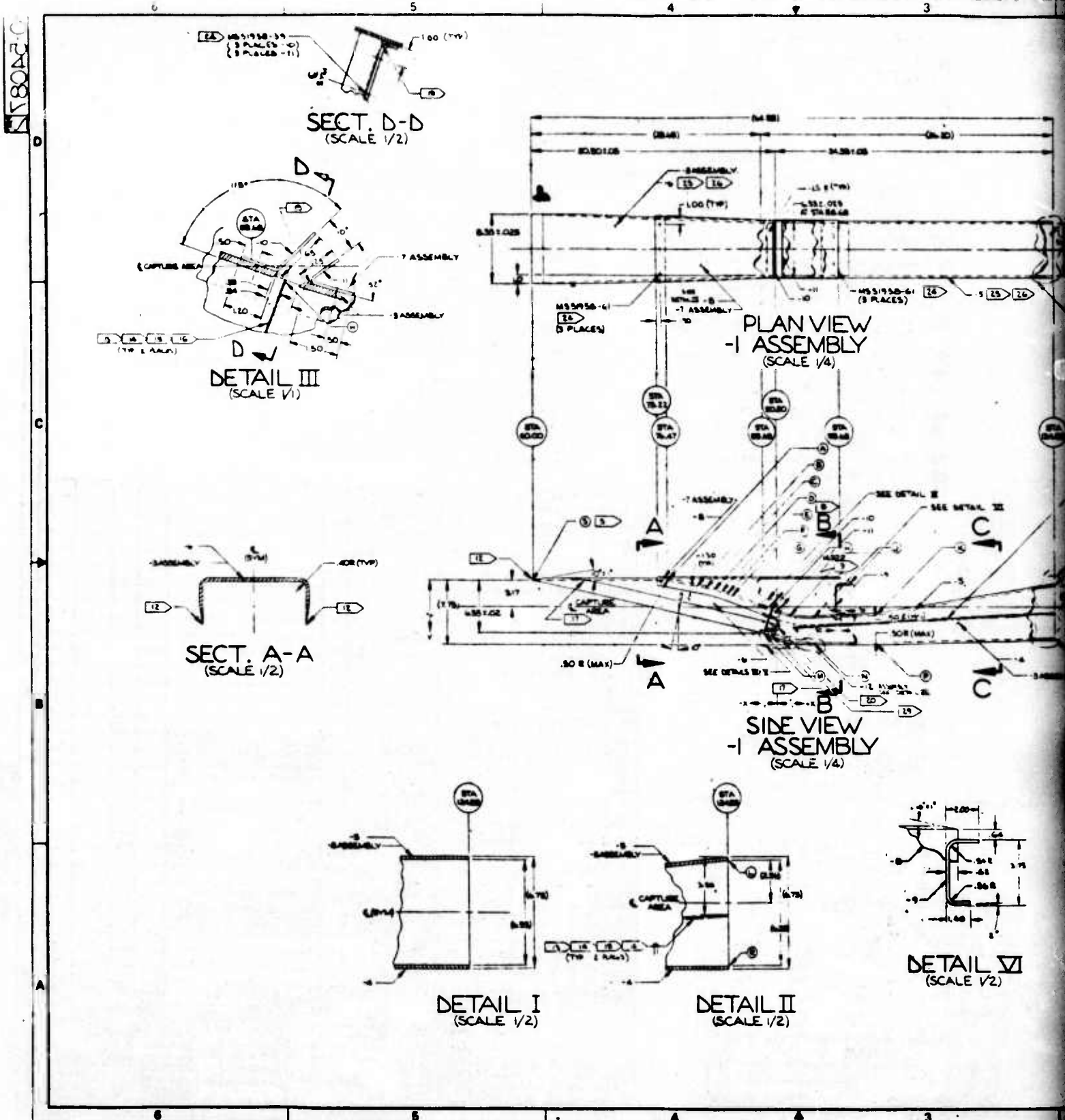
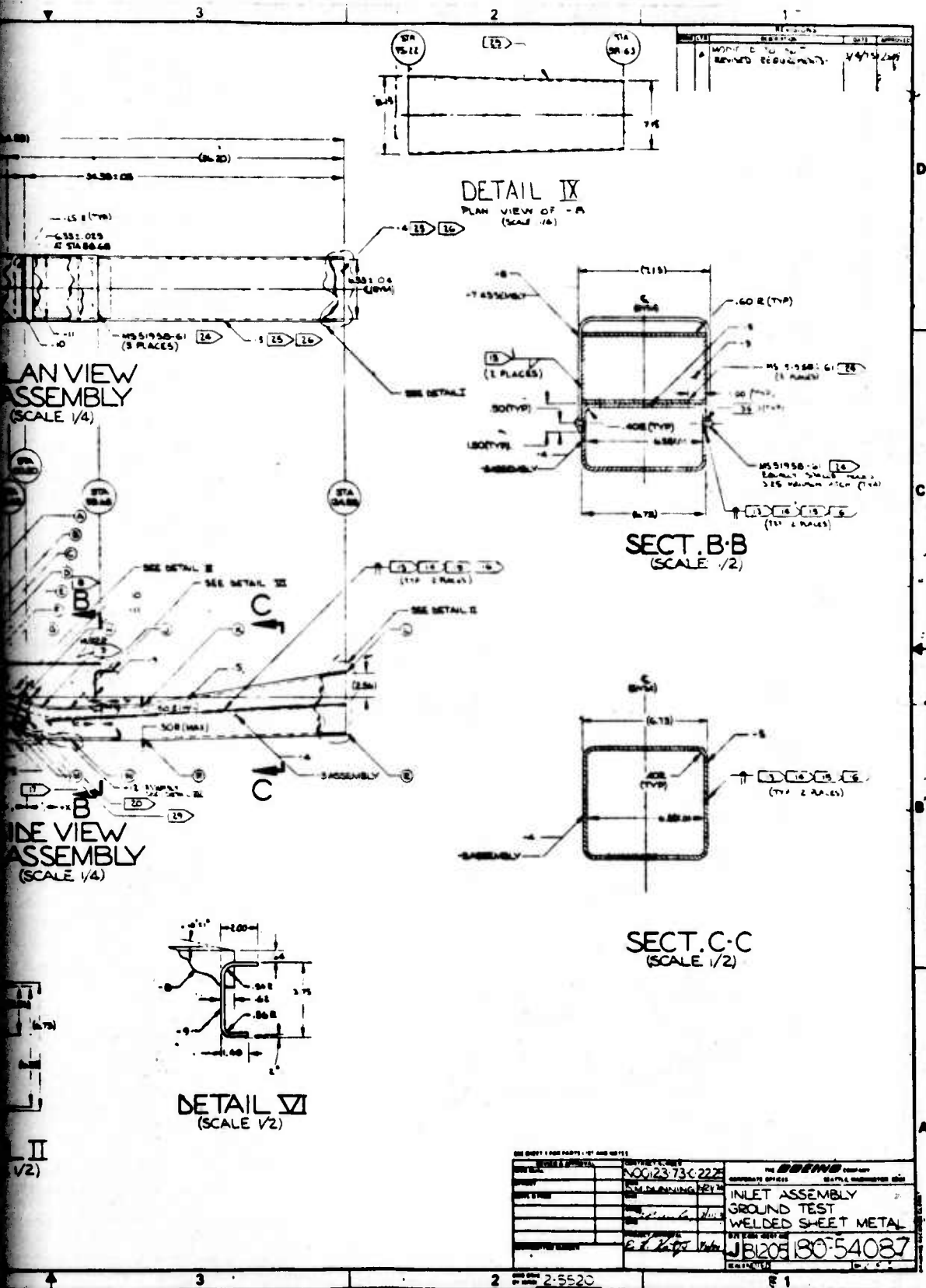


Figure 10: (CONTINUED).



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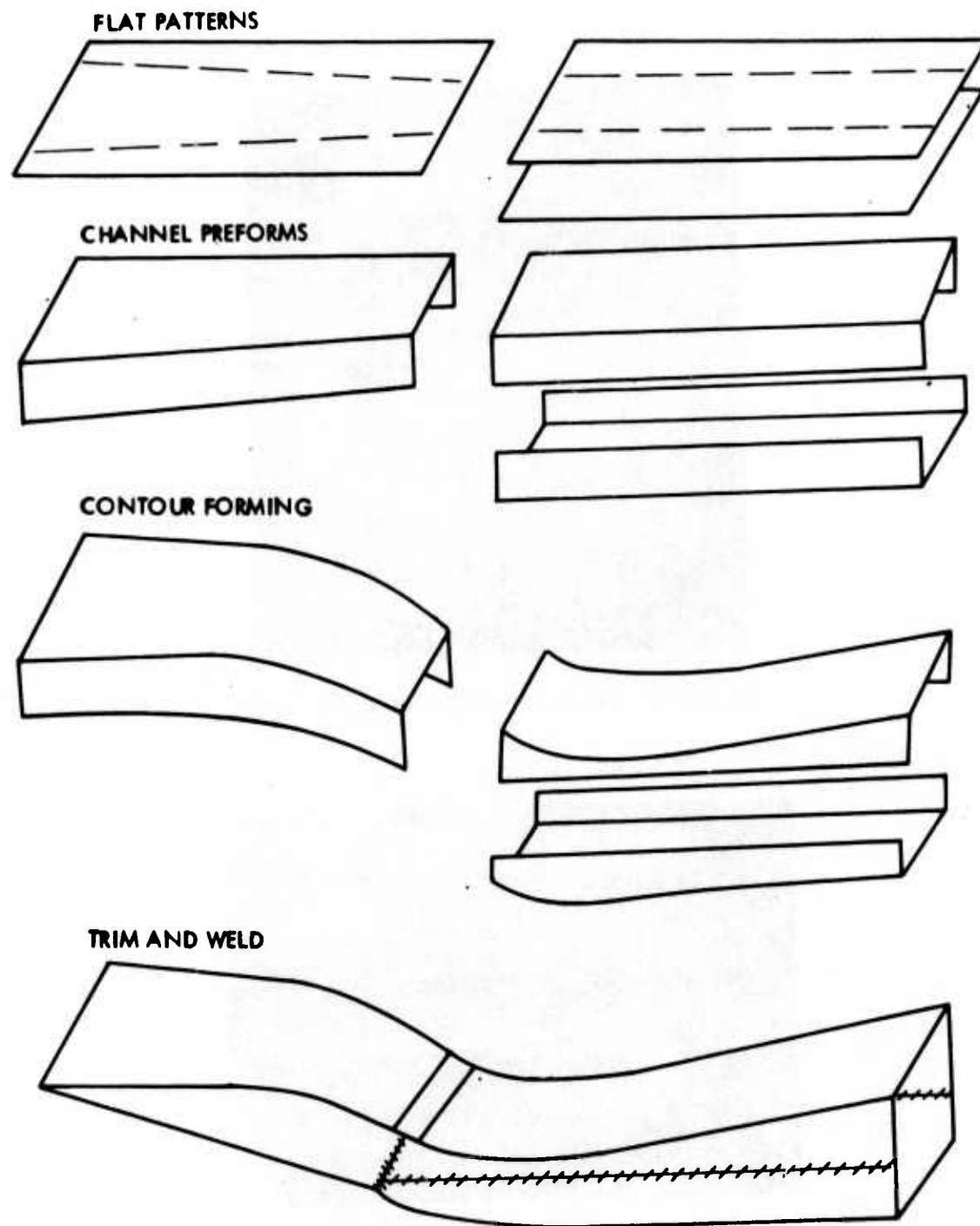


Figure 11 : BASIC FABRICATION STEPS -"PRODUCTION SIMULATION"
INLET.

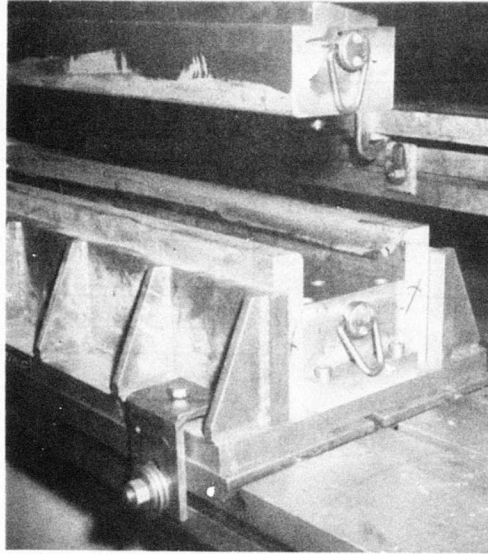


Figure 12: PREFORM DIES IN BRAKE PRESS.

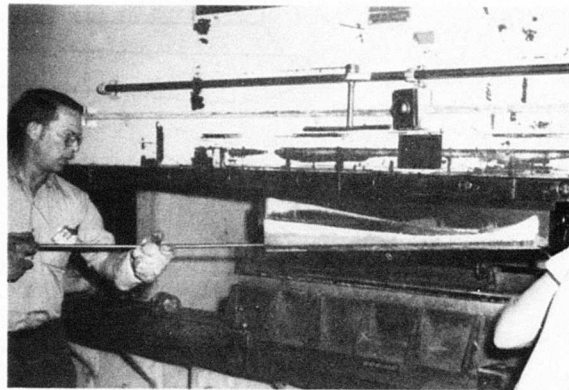


Figure 13: REMOVAL OF PREFORMED PART FROM DIES.

as shown in Figure 13. Figures 14 and 15 show the completed preforms of the three portions of the duct. The holes near the ends of the part were used to prevent slippage and misalignment of the metal during forming.

The longitudinal contour of each of the three pieces was formed in two stages. The first stage was similar to the preform operation using cold dies to form the part to approximate contour. The second stage used heated dies with both vertical and lateral pressure applied and with the part held under temperature and load for approximately 1/2 hour in order to allow creep of the metal to final contour. Figure 16 shows the precompression shroud after the first stage of the contour forming. Some compression buckling of the flange can be seen in the severely formed area of the part. The application of lateral pressure in the second stage removed these buckles and resulted in a part well within the ± 0.5 mm (± 0.02 in.) contour tolerance and 0.005 mm/mm (0.005 in./in.) waviness tolerance originally required. Figures 17 and 18 show the upper half of the duct and the second stage contour dies. Figure 19 shows the part and dies in the hot sizing furnace and Figure 20 shows the completed part.

The subassembly of the two duct halves was done with a two pass external TIG weld. Preliminary tests were conducted on flat sheet metal specimens to develop the details of the weld preparation and welding procedure. Results of these preliminary tests showed a transverse weld shrinkage of approximately 0.5 mm (0.020 in.) was to be expected with weld underbead contour within ± 0.25 mm (± 0.010 in.) of the base metal surface. Figure 21 shows the weld machine and Figure 22 is a view of the completed weld at the aft end of the duct.

The precompression shroud was welded to the duct portion using manual TIG welds and a weld fixture as shown in Figure 23. Three weld passes were used on this weld -- two external and one internal. The internal bead was then ground off to produce a smooth internal contour throughout the cowl lip and throat areas. The weld beads were left "as welded" in the subsonic diffuser portion of the inlet.

Final matching of the inlet details was accomplished using standard procedures for titanium machining with some hand grinding and filing in corner areas to avoid costly tooling. The design of the bleed slot area was modified slightly to add a removable 1.27 mm (0.050 in.) thick spacer at the aft edge of the slot. This feature will allow rapid modification of the bleed area during wind tunnel testing. This spacer plate can be seen in Figure 24 along with the FMS probe and splitter. The small holes in the sidewalls were tapped for attachment of the bleed plenum. These holes will be filled flush with the surface prior to wind tunnel testing. Figure 25 shows the detail of the leading edges on the cowl and precompression shroud. The curved intersection area of the cowl lip and shroud leading edge was found to be costly and difficult to machine. A modification of the design in this area should be considered in future designs.

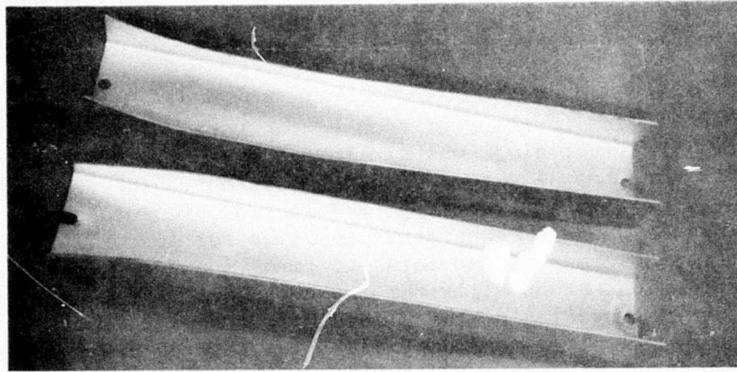


Figure 14: PREFORMS FOR UPPER AND LOWER DUCT HALVES.

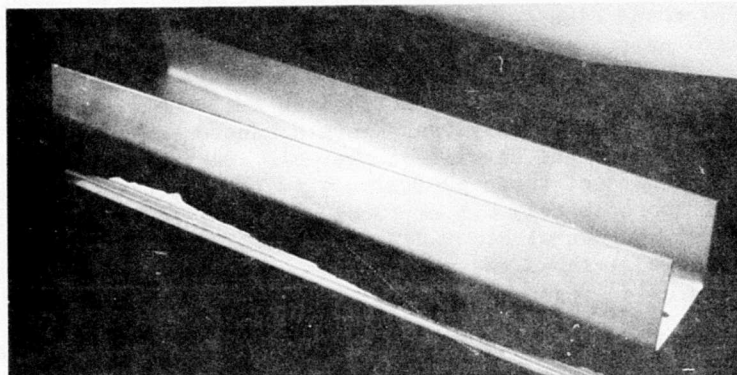


Figure 15: PREFORM FOR PRECOMPRESSION SHROUD.

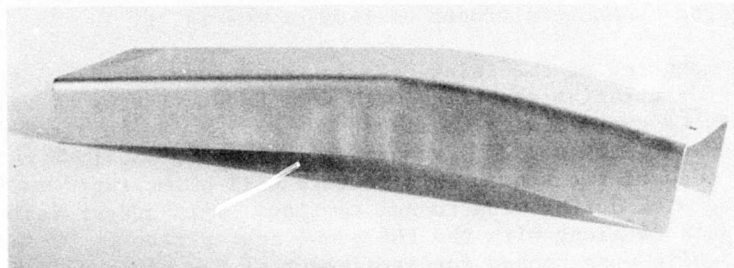


Figure 16: PRECOMPRESSION SHROUD AFTER FIRST STAGE OF CONTOUR FORMING.

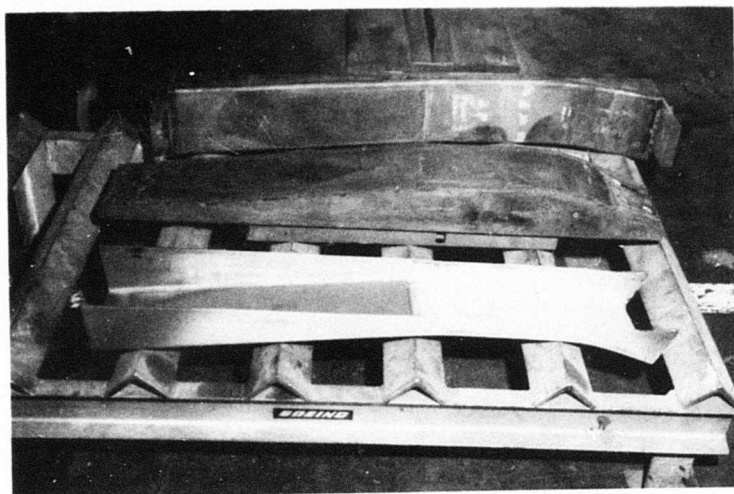


Figure 17: UPPER DUCT HALF WITH SECOND STAGE CONTOUR DIES.



Figure 18: UPPER DUCT HALF LOADED INTO SECOND STAGE CONTOUR DIES.

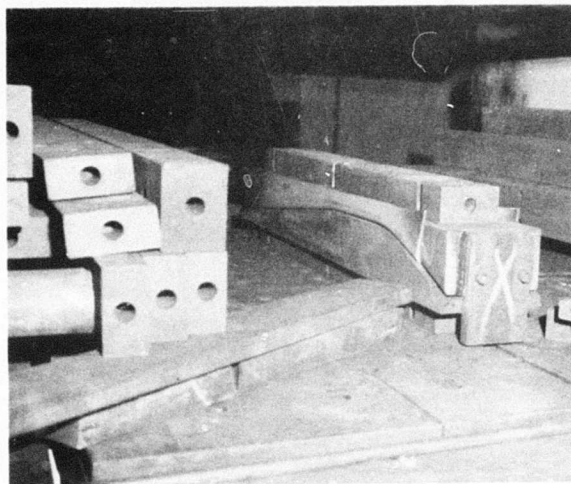


Figure 19 : UPPER DUCT HALF AND SECOND STAGE DIES
IN HOT SIZING FURNACE.

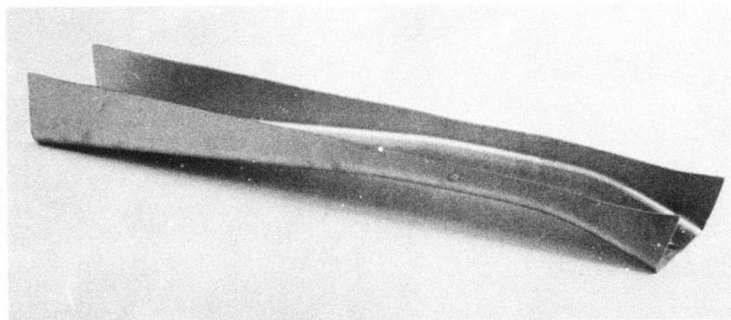


Figure 20: UPPER DUCT HALF AFTER SECOND STAGE CONTOUR FORMING.

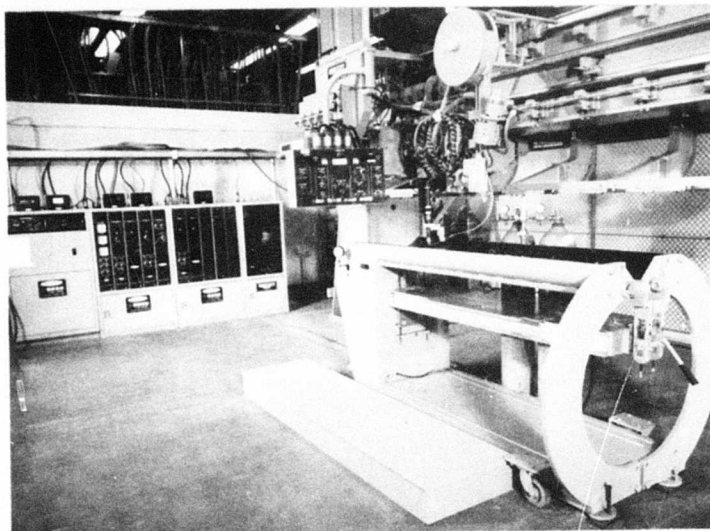


Figure 21 : AUTOMATIC TIG WELDER.

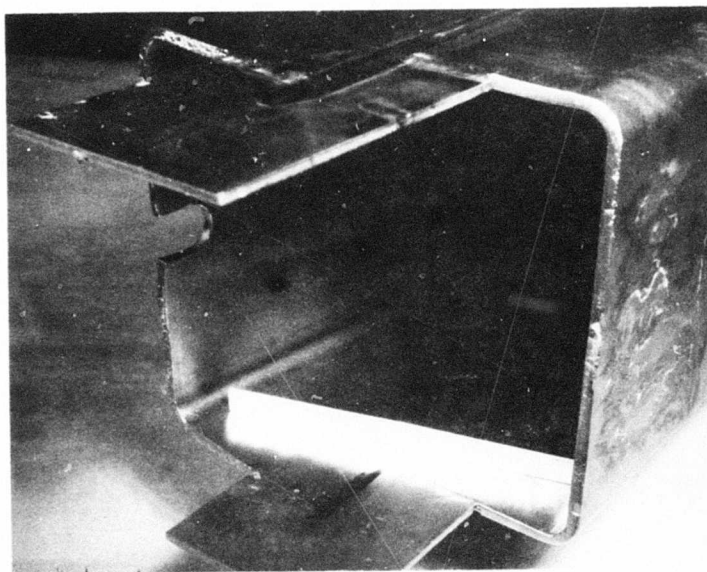


Figure 22 : COMPLETED WELD AT AFT END OF DUCT.

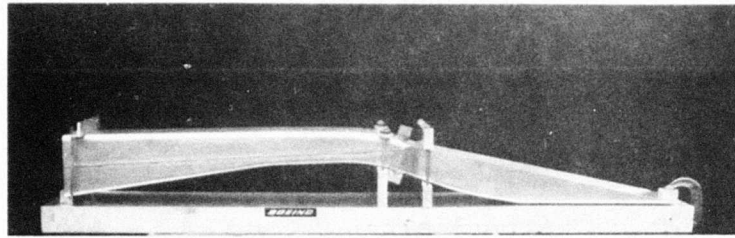


Figure 23: INLET WELDMENT SHOWING LONGITUDINAL WELD OF DUCT HALVES AND VERTICAL WELD OF PRECOMPRESSION SHROUD.

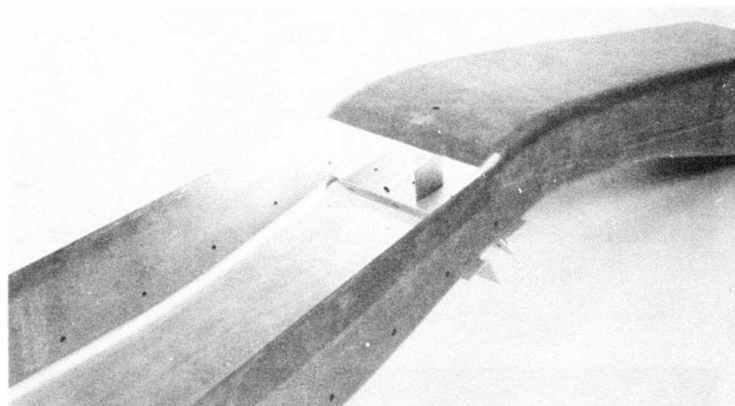


Figure 24: COMPLETED PART SHOWING COWL LIP, SPLITTER, AND BLEED SLOT DETAILS.

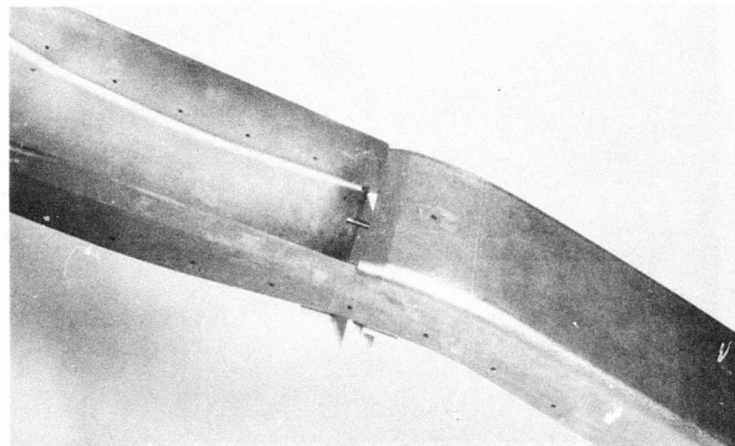


Figure 25: COMPLETED PART SHOWING LEADING EDGE DETAILS.

Figure 26 is an overall view of the completed titanium portion of the inlet. An aluminum bleed plenum was also constructed and added to complete the assembly. The aluminum plenum is for wind tunnel testing only and does not simulate production hardware except in terms of rough shape, location and flow exit venturi detail as shown in Figure 10.

The results of a detailed dimensional inspection of the completed inlet are shown in Figure 27. These results show that overall both duct height and width dimensions are within original tolerances, except for minor deviations.

Figure 28 shows the comparison of actual duct area with original requirements. The area variations are within original tolerances except at Station 95 where the area is 0.03% too large and at the exit (Station 124.88) where it is 0.64% too large. These minor deviations will have no measurable effect on either mass flow or pressure recovery of the inlet.

It should be noted that the dimensional variations of this part compared to the original nominal dimensions could be reduced by additional development efforts on the contours of the hot dies. The part to part variations to be expected on production parts is less than ± 0.76 mm (± 0.03 in.) on all "as formed and welded" dimensions and ± 0.25 mm (± 0.01 in.) on all machined dimensions.

Figure 29 and Table 2 show additional results of the detailed inspection. The capture area dimensions shown in Figure 29 are all within tolerance except for the width of the cowl lip. The capture area computed from these dimensions is well within the original required tolerances.

As shown in Table 2, the details of the bleed slot, bleed venturi, leading edge radii, ramp contours, wall waviness and splitter installation are all satisfactory. There was no requirement originally stated for internal surface roughness since the intent was to use the part in the "as formed" condition. The measured roughness values vary from 0.5 micron (20 microinches) to 2.8 microns (110 microinches) with the higher values only in local small areas in the subsonic diffuser. Roughnesses measured in the supersonic areas do not exceed 1.7 microns (65 microinches). The original requirement for smoothness of the weld beads - 0.8 micron (32 microinches) in the throat area was found to be very difficult and costly to achieve due to restricted access. The 1.3 micron (50 microinches) value actually attained is more representative of an optimum roughness for production hardware. The weld beads were left in the "as welded" condition aft of Station 98 for the same reason. The small protrusions and depressions of the longitudinal welds should have no measurable effect on the subsonic flow in this portion of the duct. Hand filing of the leading edges was found to be required to achieve the 0.13 mm (0.005 in.) radius requirement. Prior to hand filing, the edges varied from razor sharp to a 0.5 mm (0.02 in.) wide flat at the tip.

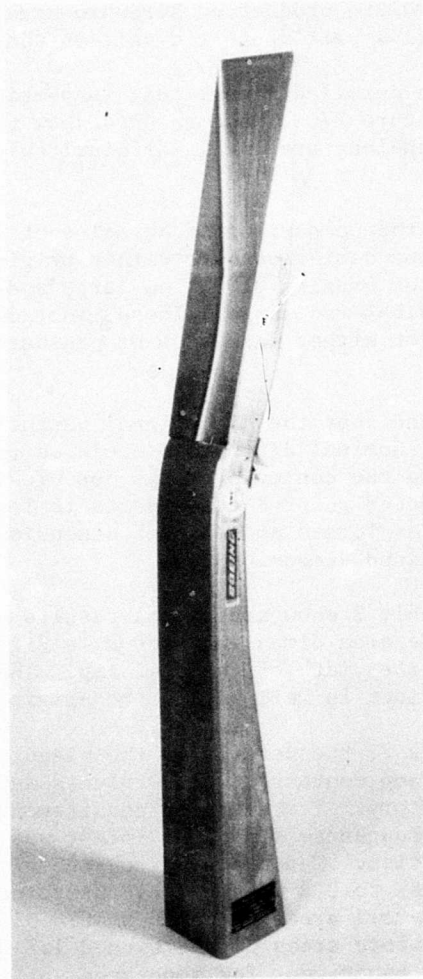


Figure 26 : COMPLETED TITANIUM DUCT PORTION OF
"PRODUCTION SIMULATION" INLET.

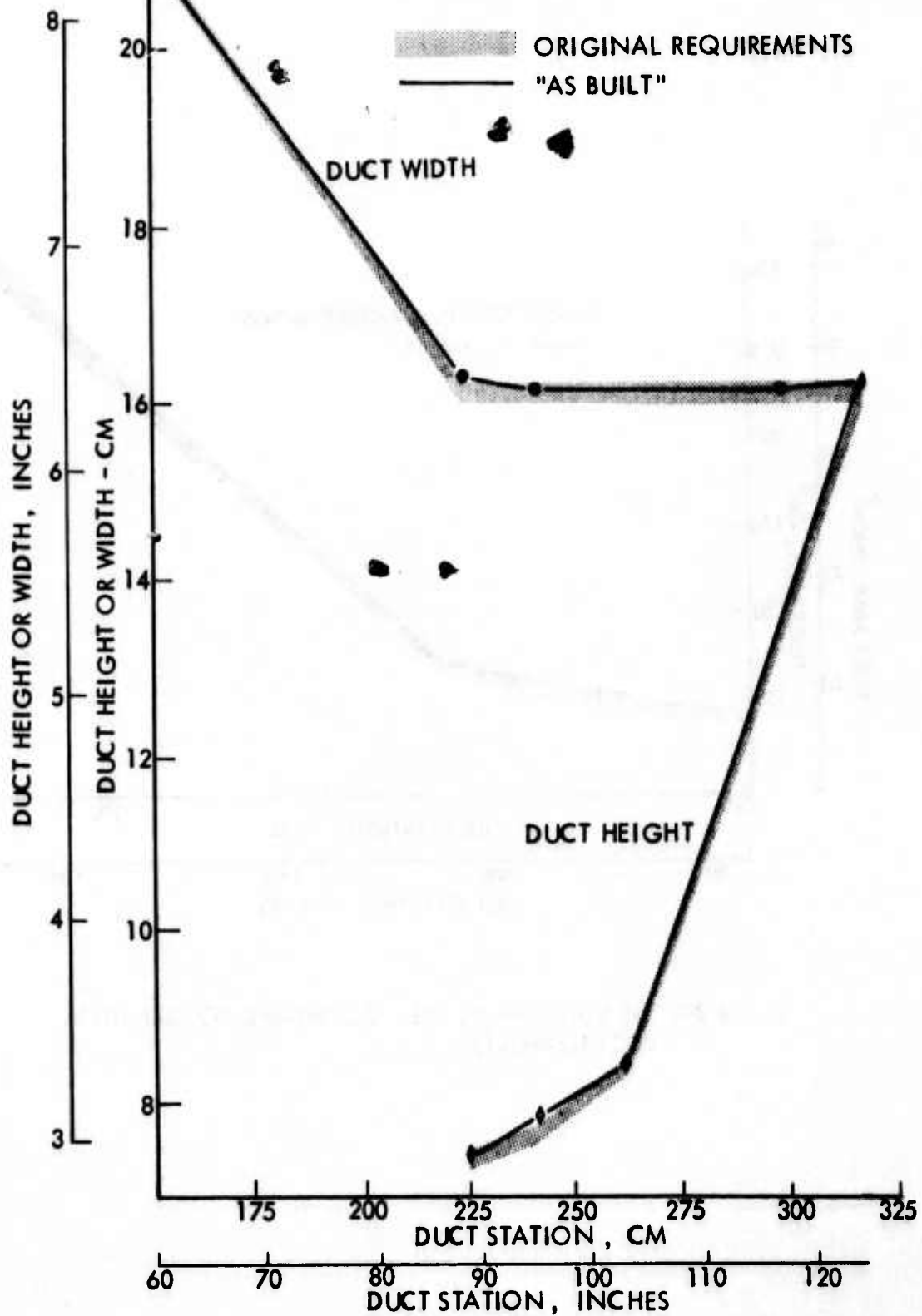


Figure 27: "AS BUILT" DUCT DIMENSIONS COMPARED TO ORIGINAL REQUIREMENTS.

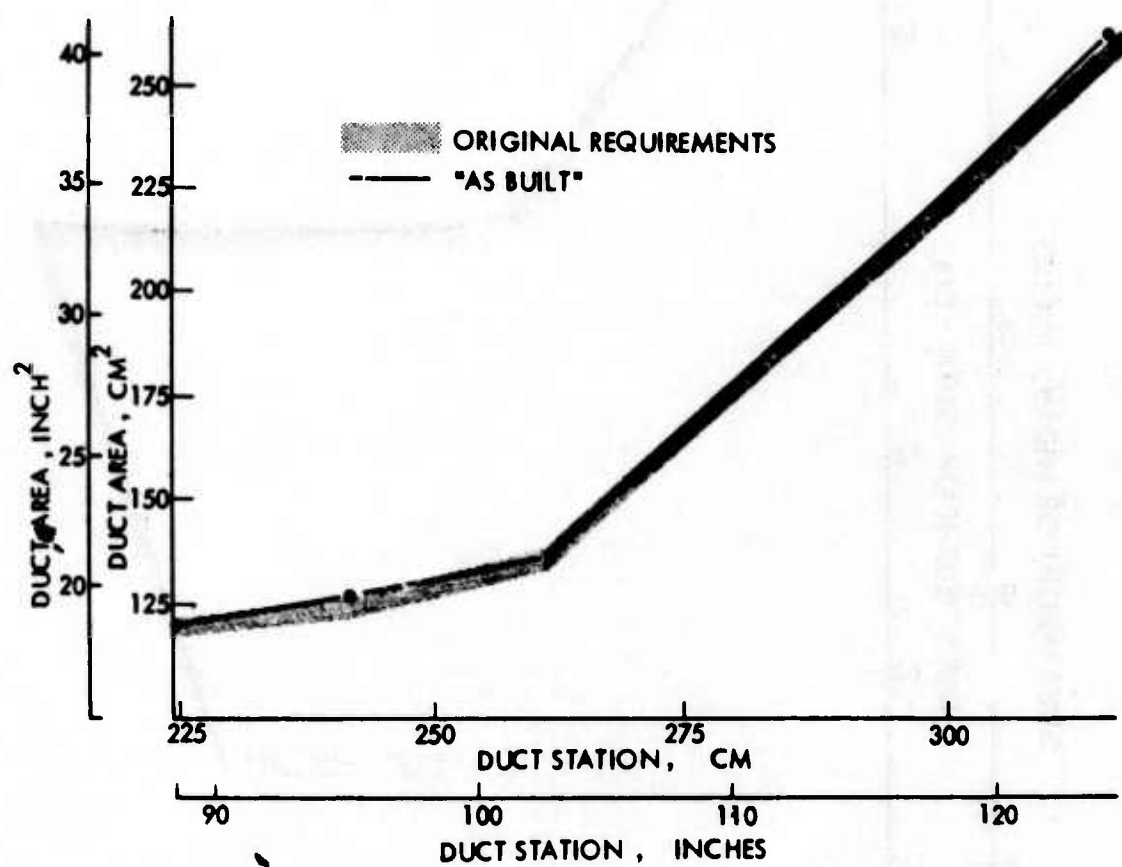
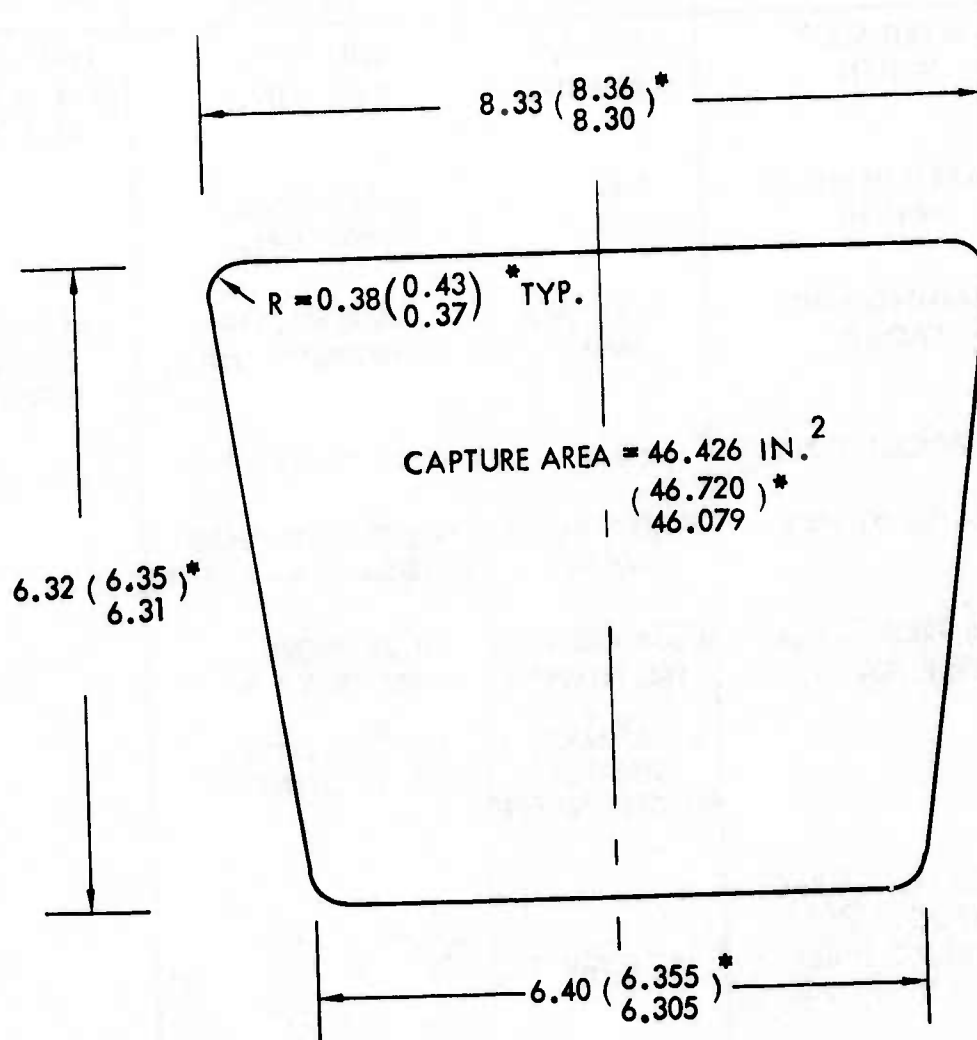


Figure 28: "AS BUILT" DUCT AREA COMPARED TO ORIGINAL REQUIREMENTS.



* NUMBERS IN PARENTHESES ARE ORIGINAL REQUIREMENT DIMENSIONS. NUMBERS NOT IN PARENTHESES ARE "AS BUILT" DIMENSIONS.

Figure 29 : COMPARISON OF "AS BUILT" CAPTURE AREA DIMENSIONS WITH ORIGINAL REQUIREMENTS.

Table 2 : COMPARISON OF "AS BUILT" DETAILS
WITH ORIGINAL REQUIREMENTS.

ITEM	ORIGINAL REQUIREMENT	ACTUAL "AS BUILT"	COMMENTS
BLEED SLOT WIDTH	0.87 MAX. 0.81 MIN.	0.86 MAX. 0.84 MIN.	REMOVABLE SPACER ADDED FOR TEST
BLEED VENTURI HEIGHT	0.67 0.61	0.675 MAX. 0.660 MIN.	
LEADING EDGE RADIUS	0.005 IN. MAX.	0.005 IN. OR EQUIVALENT MAX.	HAND FILING OF EDGE REQUIRED
RAMP CONTOUR	± 0.02	LESS THAN ± 0.02	
WALL WAVINESS	± 0.005 IN./IN. MAX.	NIL (EXCEPT WELD BEADS AFT OF STA 98)	
FMS PROBE AND SPLITTER	0.80 \pm 0.03 PROBE PROTRUSION $\pm 0.5^\circ$ MAX. SPLITTER MISALIGNMENT	0.78 PROBE PROTRUSION 0.5 $^\circ$ SPLITTER MISALIGNMENT	
INTERNAL SURFACE ROUGHNESS (EXCEPT WELD BEADS AFT OF STA 98)	AS FORMED	20 \sqrt TO 65 \sqrt WITH 80 \sqrt & 110 \sqrt IN SEVERAL SMALL LOCAL AREAS AFT OF STA 98	
WELD BEAD ROUGHNESS	32 \sqrt	50 \sqrt FWD OF STA 98 AS WELDED AFT OF STA 98 WITH 0.01 MAX. PROTRUSION, DEPRESSION AND MISMATCH	

Hand filing of these edges is neither difficult nor costly as long as local increases in the external chamfer angle up to 15 degrees can be tolerated. This local increase will apply only to a 6.35 mm (0.25 in.) width adjacent to the tip as discussed in Section 5.2.

AS BUILT DRAWINGS

Figure 30 shows the "as built" configuration of the "production simulation" inlet. The intent of this drawing is to document the dimensions and details of the part in a convenient fashion for future use.

1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 26

Figure 30 : INLET ASSEMBLY GROUND TEST

2

LET ASSEMBLY GROUND TEST "AS BUILT" WELDED SHEET METAL.

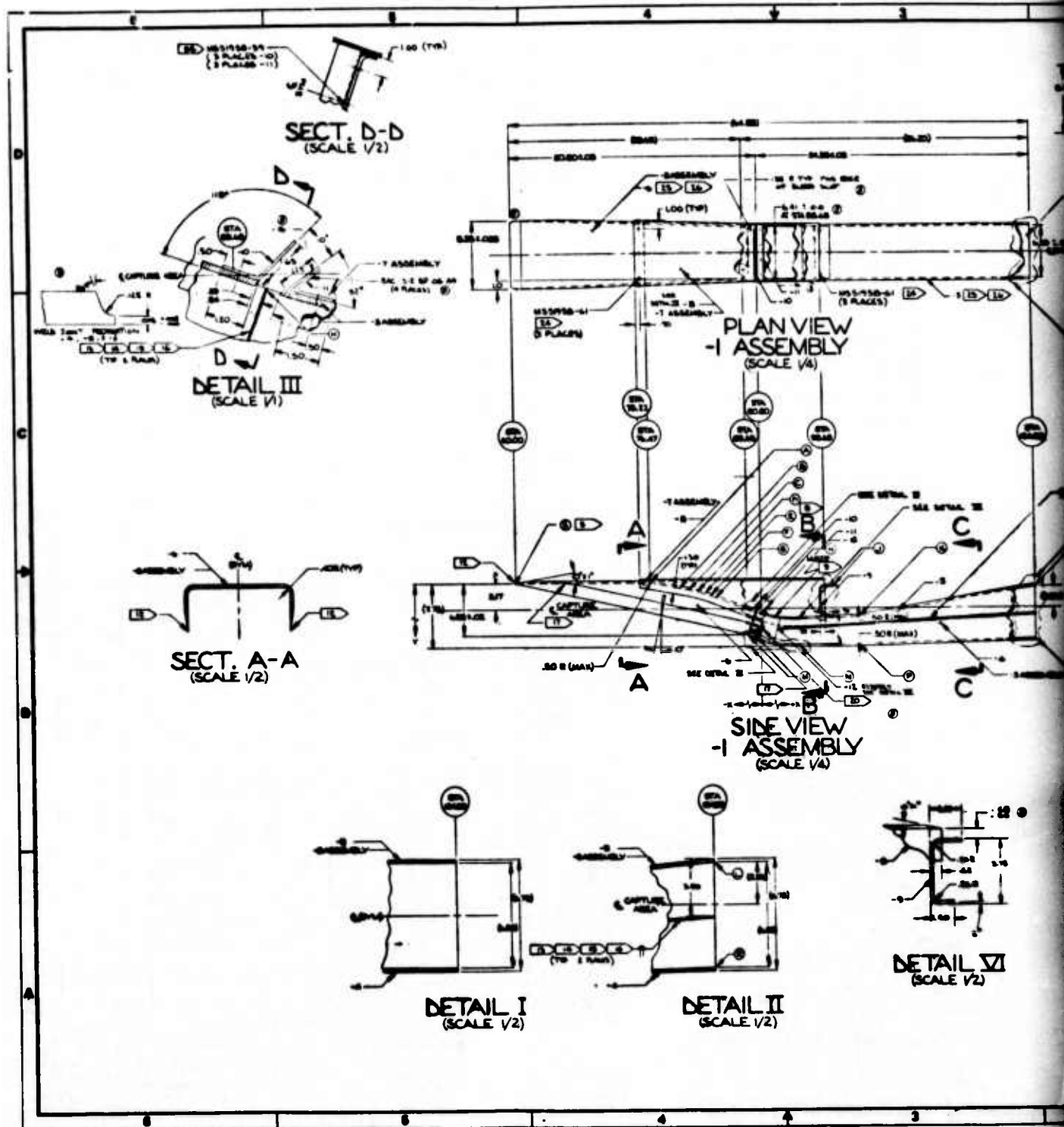
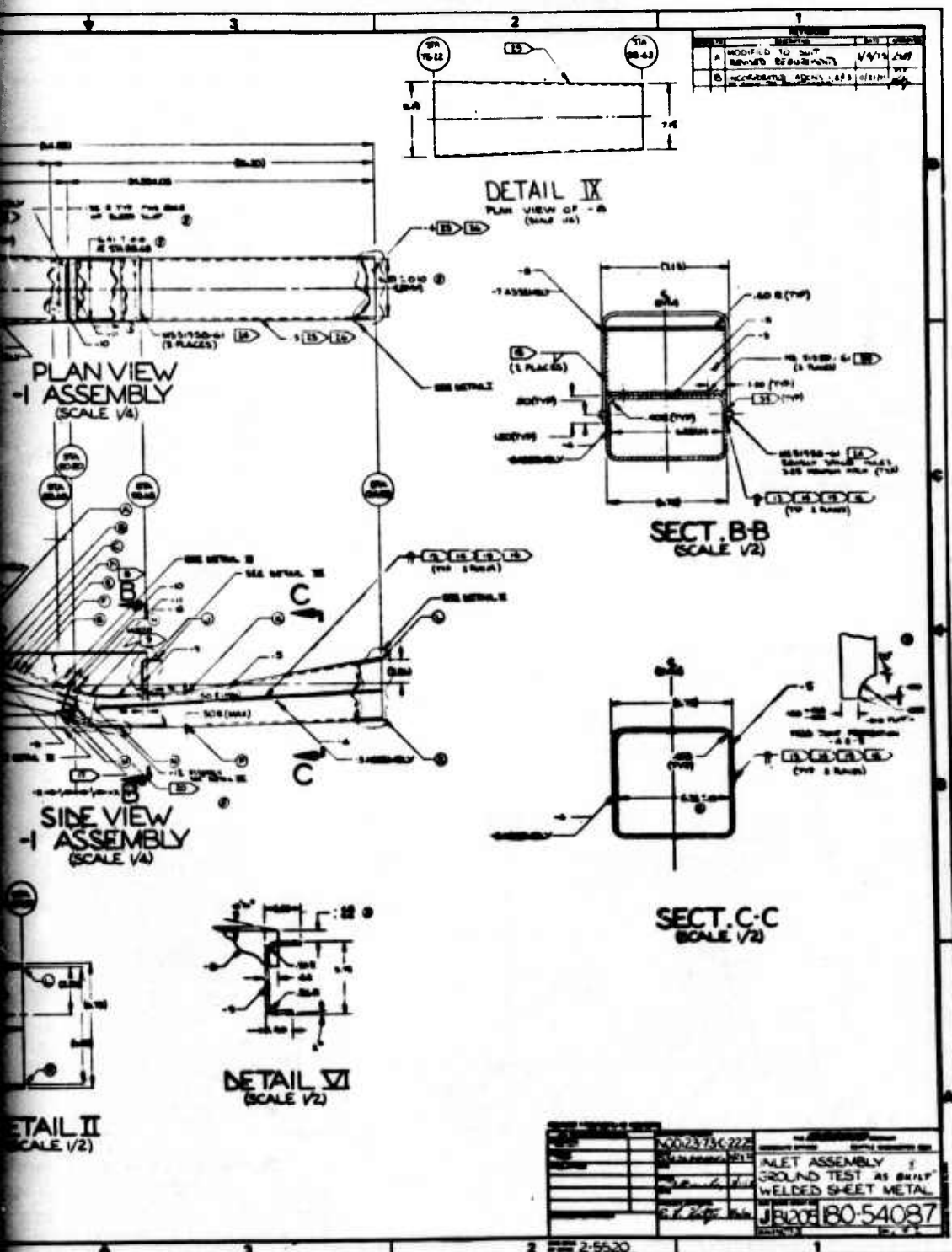


Figure 30 : (CONTINUED).



**COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**

REEVALUATION OF PRODUCTION DESIGN

As a result of the developmental efforts described previously a re-evaluation of the production design was conducted. Several recommended design changes were developed and revised production cost and weight estimates were made.

PRODUCTION DESIGN

Figure 32 shows the key features of the production design developed in Phase I of this study per Boeing drawing 180-54089 (see NWCTP 5705, Volume 1).

RECOMMENDED CHANGES TO THE PRODUCTION DESIGN

Several recommended design changes were developed to further reduce production costs without significant reduction in inlet or missile performance.

The welds specified on the drawing should have optional locations to allow fabrication of the upper half of the duct and the precompression shroud from a single sheet, as shown in Figure 31.

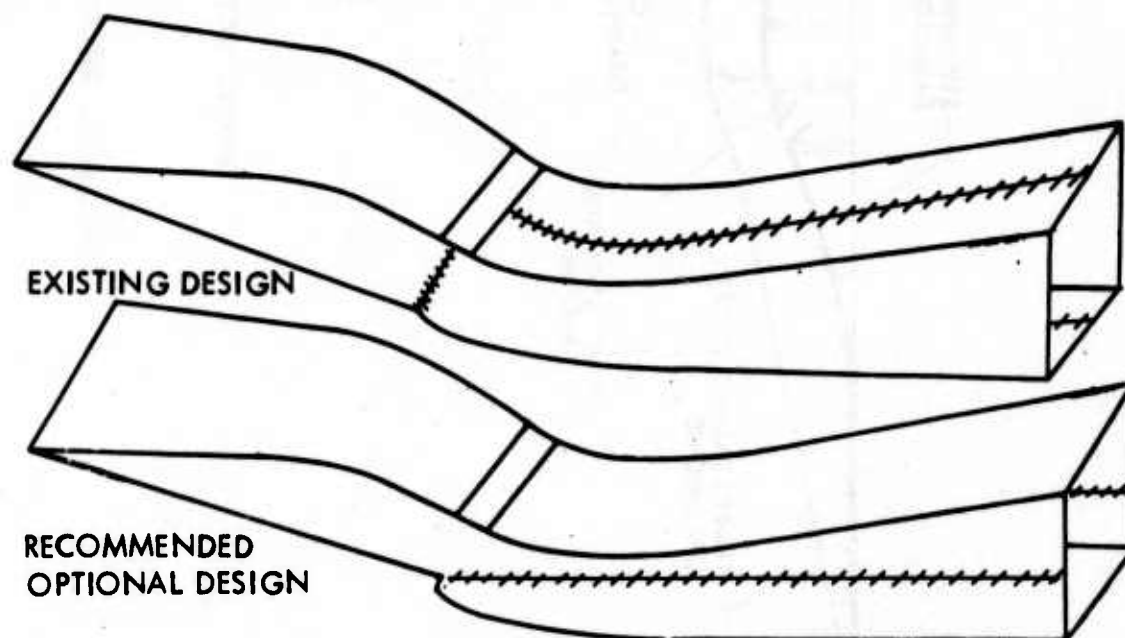


Figure 31: RECOMMENDED MODIFICATION TO WELDMENT DETAIL DESIGN

The cowl lip area detail should be modified to simplify the intersection of the precompression shroud sidewalls with the cowl lip as shown in Figure 33.

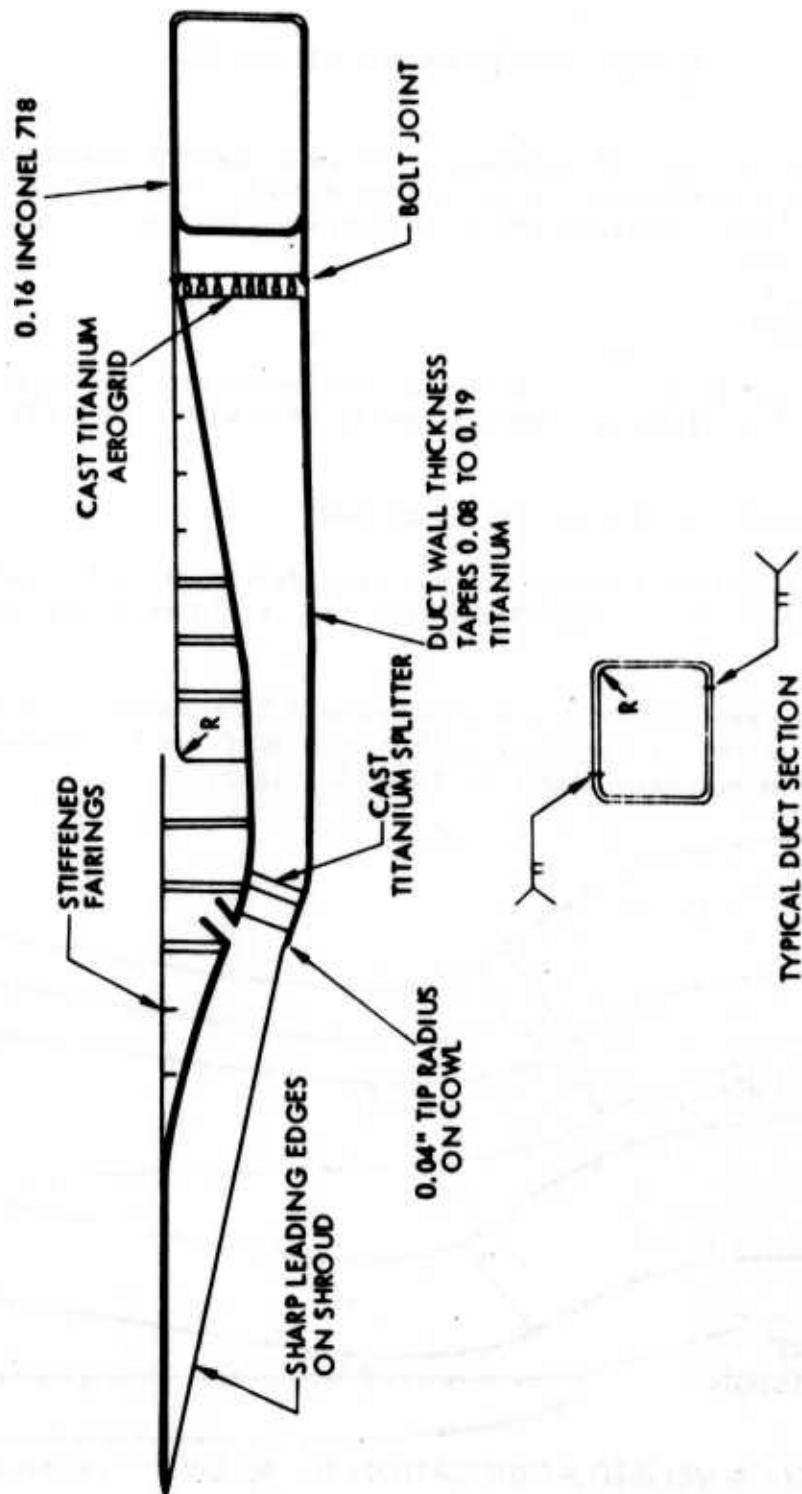


Figure 32 : FINAL DESIGN FEATURES.

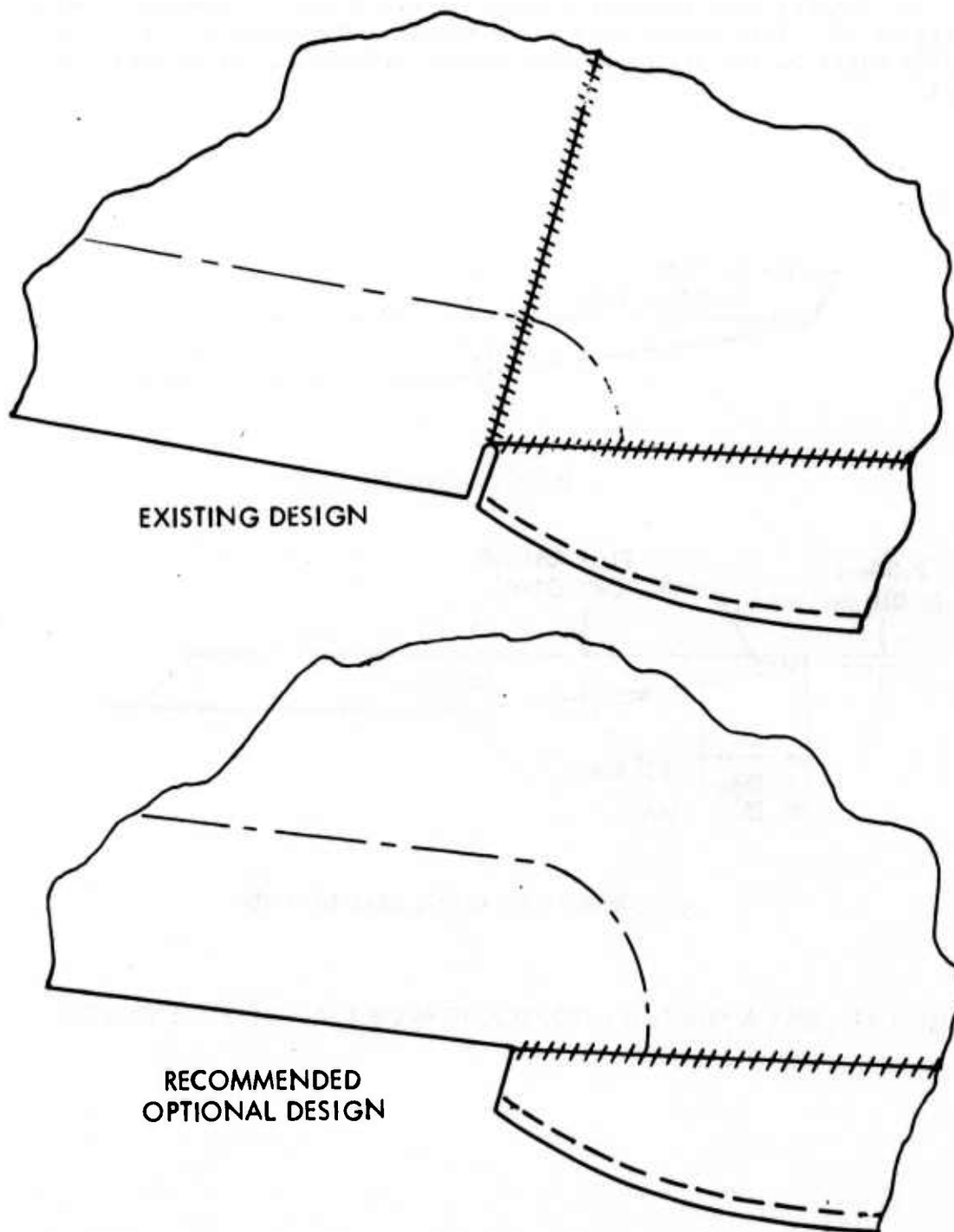


Figure 33: RECOMMENDED MODIFICATION OF COWL LIP DETAIL DESIGN.

The leading edge external chamfer detail should be changed as shown in Figure 34. This change will allow rapid hand finishing of the sharp leading edges on the precompression shroud without extensive metal removal.

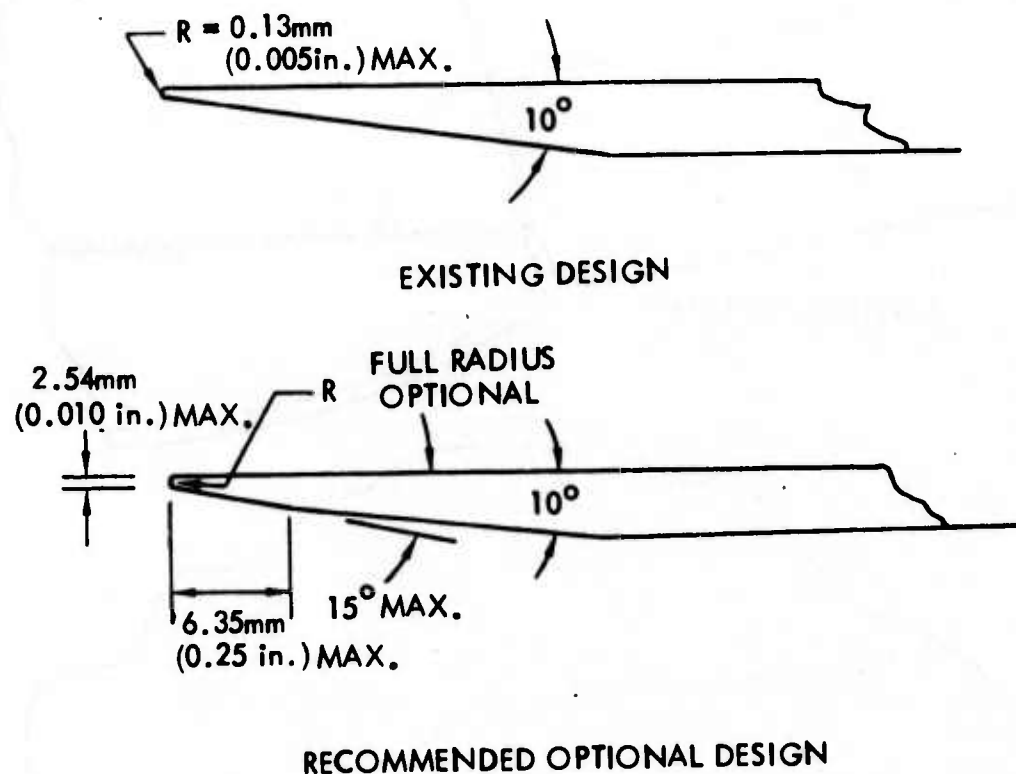
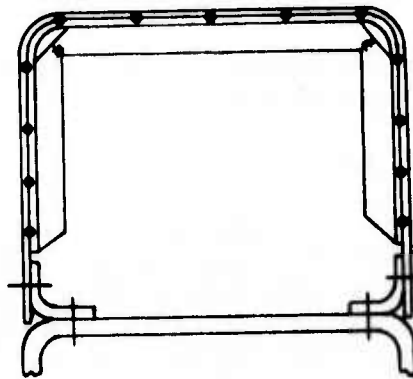


Figure 34: RECOMMENDED MODIFICATION OF LEADING EDGE DESIGN

The design of the forward and aft fairings, fairing stiffeners and fairing attachment provisions should be modified as shown in Figure 35 to further reduce weight and costs.

EXISTING
DESIGN



RECOMMENDED
OPTIONAL
DESIGN

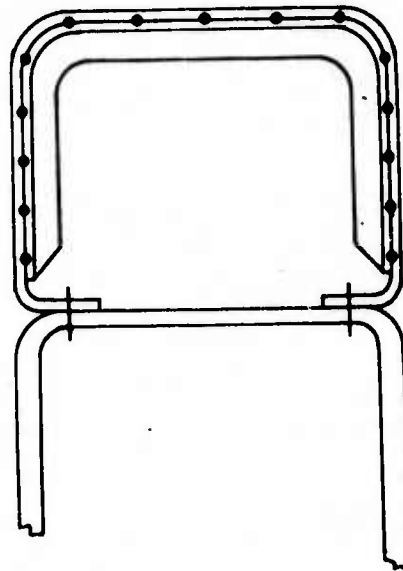


Figure 35: RECOMMENDED MODIFICATION OF FAIRING DESIGN

REVISED COST ESTIMATE

A revised production cost estimate was made based on the experience gained in fabrication of the "production simulation" hardware and the recommended design modifications discussed above.

The revised manufacturing plan is outlined in Table 3 and the resulting production cost breakdown is outlined in Table 4.

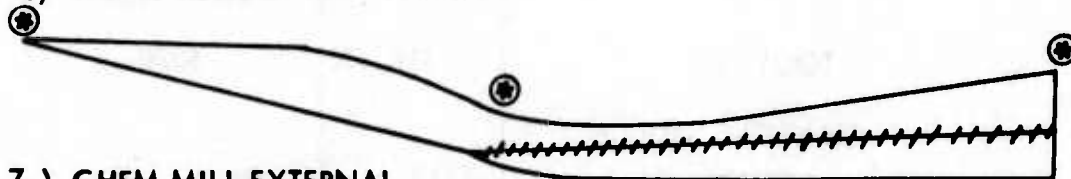
Results show the inlets can be built for \$3390 per set compared to the original estimate of \$4985.

REVISED WEIGHT ESTIMATE

The inlet weight estimate was updated based on better definition of details and recommended design changes. Results show the weight of the inlet will be 47.2 kg (104 lbs.). This weight includes the turn and dump section, fairings and diverter, but does not include the aerogrid, splitter, flameholder, injectors, igniter or provisions for their attachment. The previous estimate used in the trade study was 48.6 kg (107 lbs.).

Table 3: REVISED MANUFACTURING PLAN OUTLINE FOR
PRODUCTION INLETS.

- 1.) FLAT PATTERNS -4 & -5
- 2.) PREFORM ON COLD DIES - HOT METAL
- 3.) HOT FORM CONTOUR ON INTREGRAL HEATED INCONEL OR
STAINLESS TOOLS
- 4.) TRIM AND WELD PREPARATION
- 5.) LONGITUDINAL WELD TIG WITH BACKUP - 2 PASS WELD
- 6.) STRESS RELIEVE WITH FIXTURE



- 7.) CHEM MILL EXTERNAL
- 8.) MACHINE DETAILS
AFT END
BLEED SLOT
ROUGH CUT LEADING EDGES
- 9.) CLEAN
- 10.) FORM AND WELD TURN AND DUMP - INCONEL 718
- 11.) FORWARD FAIRING AND STIFFENERS
- 12.) AFT FAIRING STIFFENERS AND ATTACH FITTING
- 13.) DIVERTER AND BLEED FLARE ANGLES
- 14.) AERO GRID AND SPLITTER - GFE
- 15.) ASSEMBLY
- 16.) HAND FINISH LEADING EDGES
- 17.) CLEAN
- 18.) NAME PLATE
- 19.) PACKAGE

Table 4: REEVALUATED COST ESTIMATES
FOR "PRODUCTION INLETS".

	10 SETS	1000 SETS
MATERIALS	\$2,000	\$1,020
TOOLING	\$10,430	\$320
MANUFACTURING		
SETUP	\$510	\$20
RUN	\$5,880	\$2,030
SUB TOTAL	\$6,390	\$2,050
TOTAL ^a	\$18,820	\$3,390

^a AVERAGE COST PER SET FOR 10 OR 1000 SET
PRODUCTION IN MID 1974 DOLLARS

INITIAL DISTRIBUTION

13 Naval Air Systems Command

- AIR-03B (1)
- AIR-03P2 (1)
- AIR-30212 (2)
- AIR-320C, W. Volz (1)
- AIR-330F (1)
- AIR-503 (1)
- AIR-503E (1)
- AIR-5108 (1)
- AIR-5109 (1)
- AIR-5203 (1)
- AIR-5351 (1)
- AIR-5366 (1)

3 Chief of Naval Material

- MAT-030B (1)
- MAT-032 (1)
- NSP-27 (1)

2 Naval Sea Systems Command

- SEA-0332 (1)
- SEA-04H (1)

1 Air Test and Evaluation Squadron 5 (LT Karl Kail)

- 1 Naval Ammunition Depot, Hawthorne (Code 05, Robert Dempsey)
- 1 Naval Explosive Ordnance Disposal Facility, Indian Head
- 1 Naval Intelligence Support Center (OOXA, CDR Jack Darnell)
- 1 Naval Ship Research and Development Center, Bethesda (Code 166, John F. Talbot)
- 1 Naval Surface Weapons Center, White Oak (Code 312, W. C. Ragsdale)
- 1 Naval Undersea Center, San Diego (Code 133)
- 1 Naval Intelligence Support Center Liaison Officer (LNN)
- 1 Army Armament Command, Rock Island Arsenal (AMSAR-SF)
- 1 Army Missile Command, Research and Development Directorate, Redstone Arsenal (AMSMI-RK, Dr. R. G. Rhoades)

4 Picatinny Arsenal (SMD, Concepts Branch)

3 Air Force Systems Command, Andrews Air Force Base

- DLFP (1)
- DLW (1)
- SDW (1)

5 Air Force Armament Laboratory, Eglin Air Force Base

- DLD (1)
- DLJW (1)
- DLO (1)
- DLQ (1)
- DLR (1)

1 Foreign Technology Division, Wright-Patterson Air Force Base (Code PDXA, James Woodard)
5 Wright-Patterson Air Force Base
 AFAPL
 RJA (1)
 RJT (1)
 STINSO (1)
 XRDP (1)
 XRHP (1)
1 Defense Advanced Research Projects Agency, Arlington
2 Defense Documentation Center
1 Explosives Safety Board (6-A-145)
1 Langley Research Center (Chas. M. Jackson, Jr.)
1 Applied Physics Laboratory, JHU, Laurel, Md. (W. B. Shippen)
1 Beech Aircraft Corporation, Wichita, Kan.
1 Convair Division of General Dynamics, San Diego, Calif.
1 Grumman Aerospace Corporation, Bethpage, N. Y.
1 Honeywell Inc., Systems & Research Division, Minneapolis, Minn.
1 Hughes Aircraft Company, Culver City, Calif.
1 Hughes Aircraft Company, Missiles Systems Division, Canoga Park, Calif.
1 McDonnell Douglas Corporation, St. Louis, Mo. (Astronautics, A. N. Thomas)
1 Marquardt Corporation, Van Nuys, Calif.
1 North American Rockwell Corporation, Columbus, Ohio (R. C. Wykes)
1 Purdue University, School of Mechanical Engineering, Lafayette, Ind. (Cecil F. Warner)
1 Ryan Aeronautical Company, San Diego, Calif.
5 The Boeing Company, Seattle, Wash.
1 The Martin Company, Orlando, Fla.
1 United Aircraft Corporation, East Hartford, Conn. (Research Laboratories, R. L. O'Brien)
101 Chemical Propulsion Mailing List No. 271 dated October 1975, including Categories 1,2,3,4,5